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Original Research Paper

Integrated Digitization Evaluation of Soil Fertility in Coal Mine Reclamation Area

XiaoLong Li, JinXiang Yang, MingXu Zhang, Liangmin Gao and Duoxi Yao
The School of Earth and Environment, Anhui University of Science and Technology, Huainan, Anhui, 232001, China

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ABSTRACT

Along with the increase of population, land resources are becoming more and more precious. Therefore, the evaluation of the reclaimed soil fertility is very important. The level of soil fertility is comprehensive reflection of many basic properties of soil, and is closely related to soil quality. In this paper, integrated digitization evaluation of soil fertility is used to evaluate soil of three typical reclamation areas in Huainan city, Anhui province, China. The results show that in three reclamation areas, the order of soil fertility level is XinZhuangZi reclamation area > DaTong ecological wetland > PanYi reclamation area.

INTRODUCTION

The level of soil fertility is comprehensive reflection of many basic properties of soil, and is closely related to soil quality. Each single index is not sufficient to represent the overall level in the evaluation of soil fertility; the evaluation of integrated fertility level is required. Integrated digitization evaluation is the commonly used methods of soil fertility comprehensive evaluation, and has a lot of research application. Previous researches on comprehensive evaluation of soil fertility are limited mainly to agricultural and forestry soil; in recent years, along with the city green belt soil is taken seriously and related research work in part of the city also spread out stage by stage. Evaluation methods on soil fertility have been discussed (Larson & Pierce 1994, Liu Honghu et al. 2008, Schoenholtz et al. 2000, Shukla et al. 2006). The soil fertility of different vegetation types of urban green land in Shenzhen is studied using integrated digitization evaluation, the results show that there are significant differences in soil fertility among the landscape types, and soil fertility is in a low level (Chen Dehua et al. 2009). The integrated evaluation of tobacco soil fertility is studied with 15 nutrient indexes based on correlation analysis and fuzzy mathematic theory taking tobacco soil fertility at Chongqing in China as an example (Li Xiaoning 2007).

MATERIALS AND METHODS

Study area overview: Direct coal mining subsidence area is 101.5km^2 in Huainan mining area (in Anhui province, China), the affected area is 132.82 km^2, accounting for 5.1% of the total precinct area. Utilization of gangue filling mining subsidence has several decades of history, since 2005, Huainan Mining Group has carried out the mine geological environment governance project by stripping topsoil, backfilling is rock and overlying clay craft, to return by filling soil under plans and steps, developing planting, breeding, and processing utilization as one of the integrated agribusiness industrial, build storage establishment and residential to restore ecological environment in mining area. Therefore, the evaluation of the reclaimed soil fertility is very important.

In this paper, integrated digitization evaluation of soil fertility is used to evaluate the soil of three typical reclamation areas (DaTong ecological wetland, PanYi reclamation area and XinZhuang Zi reclamation area) in Huainan to provide a scientific basis for improving the soil utilization and management level.

Pretreatment and test of samples: Soil samples in strict accordance with the soil environmental monitor technical specification (HJ/T 166-2004) were treated. The soil samples were put in a ventilated, cool and dry place to naturally air dry. After dried, the stones, plant roots and other debris were picked out from the samples, and then according to quartering, the samples were discarded the excess part to retain about 300 g or so. Finally, the samples were put in agate mortar for grinding, passed through 2 mm nylon screen mesh for screening, and sealed into ziplock bag to prepare for determination. Testing items were pH, organic matter (OM), available phosphorus (APP), available potassium

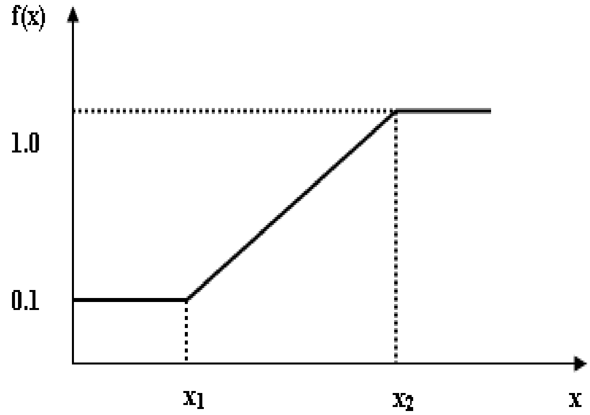

Fig.1: Membership function curve of S-type.

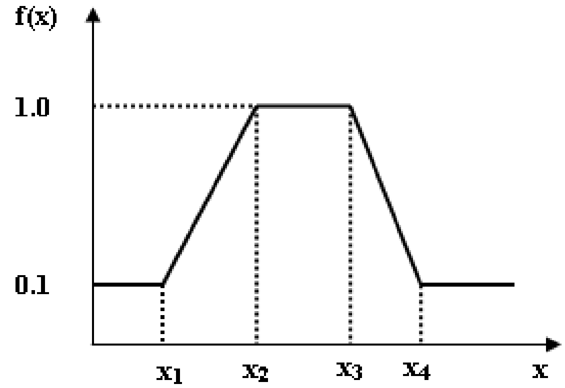

Fig. 2: Membership function curve of parabola type.

Table1: Determination methods.

Testing Items	Determination methods
pH	LY/T 1239-1999
CEC	LY/T 1243-1999
OM	NY/T 1121.6-2006
APP	LY/T 1233-1999
APT	LY/T 1236-1999

(APT) and cation exchange capacity (CEC). The determination methods are given in Table 1.

RESULTS

Calculation of evaluation index: Considering the accessibility, systematic and comprehensive evaluation index, five fertility properties i.e., pH, organic matter (OM), available phosphorus (APP), available potassium (APT) and cation exchange capacity (CEC) were selected as reference index of comprehensive evaluation of soil fertility in reclamation area.

Influence degree of fertility index on soil fertility is a fuzzy concept, as well as classification standard as fertility grade is fuzzy. Therefore, corresponding membership function is established for reference fertility index of soil to calculate their membership values which are expressed for the status value of fertility index.

The crop effect curve of organic matter, available phosphorus, available potassium and CEC is S-type, so the membership function should adopt S-type; the crop effect curve of pH parabola type, and the membership function should adopt parabola type (Lv Xiaonan et al. 2000). Then the curve function is transformed into the corresponding polygonal function for calculation (as shown in Figs. 1 and 2) and corresponding membership function is established as follow:
Membership function of S-type:

$$f(x)=\begin{cases} 1.0 & x \geq_2 \\ 0.9(x-x_1)/(x_2-x_1)-0.1 & x_1 \leq x \leq x_2 \\ 0.1 & x < x_1 \end{cases} \quad ...(1)$$

Membership function of parabola type:

$$f(x)=\begin{cases} 1.0-0.9(x-x_3)/(x_4-x_3) & x_3 < x \leq x_4 \\ 1.0 & x_2 \leq x \leq x_3 \\ 0.9(x-x_1)/(x_2-x_1)+0.1 & x_1 \leq x \leq x_2 \\ 0.1 & x < x_1 \ or \ x > x_4 \end{cases} \quad ...(2)$$

According to previous research results (Kan Wenjie & Wu Qitang 2004, Lv Xiaonan et al. 2000, Zhang Hua & Zhang Ganlin 2001), each individual fertility Plentiful-lack index for different crops and soil is different. According to the study object of this paper, combined with previous research experience, the corresponding values in turning point of the curve are determined, such as those in Tables 2 and 3.

According to membership functions of S type and parabola type and the data of Tables 1 and 2, membership value of the fertility index can be calculated, and membership value in 0.1~1.0, the maximum value of 1.0 represents that the soil fertility index is completely suitable for crop growth, the lowest value of 0.1 represents the serious lack of soil fertility. Because there is rarely zero fertility soil, so in the calculation, in order to avoid zero value, a minimum value of 0.1 is taken (Lv Xiaonan et al. 2000). The results are given in Table 4.

Determining weight coefficient of the single fertility index: Due to the influence roles of soil fertility factors (index) on overall fertility are different, namely the contribution of each index on soil fertility is inconsistent, and so each index should be given a certain weight coefficient, which is one of the key problems in the fertility comprehensive evaluation (Lv Xiaonan et al. 2000). In order to avoid the

Table 2: Corresponding values in turning point of S-type curve.

Turning point of S-type	OM (g/kg)	APT (mg/kg)	APP (mg/kg)	CEC(cmol/kg)
x_1	10	50	5	7
x_2	20	150	20	15

Table 3: Corresponding values in turning point of parabola type.

Turning point of parabola type	x_1	x_2	x_3	x_4
pH	4.5	6.5	7.5	8.5

Table 4: Membership value of the soil fertility index.

Reclamation Area	OM(g/kg)	APT(mg/kg)	APP(mg/kg)	pH	CEC(cmol/kg)
Da Tong	0.39	0.29	0.51	0.17	0.41
Pan Yi	0.1	0.42	0.07	0.35	0.86
Xin Zhuangzi	0.08	0.62	0.56	0.87	1

Table 5: Weight coefficient of the single fertility index.

Index	Da Tong	Pan Yi	Xin Zhuangzi
OM	0.202	0.231	0.217
APT	0.220	0.204	0.218
APP	0.247	0.215	0.127
pH	0.112	0.201	0.196
CEC	0.219	0.149	0.243

Table 6: Soil fertility comprehensive index value.

Index	Da Tong			Pan Yi			Xin Zhuangzi		
	Mv	Weight	$Wi \times Ni$	*Mv*	Weight	$Wi \times Ni$	*Mv*	Weight	$Wi \times Ni$
OM	0.390	0.202	0.079	0.100	0.231	0.023	0.080	0.217	0.017
APT	0.290	0.220	0.064	0.420	0.204	0.086	0.620	0.218	0.135
APP	0.510	0.247	0.126	0.070	0.215	0.015	0.560	0.127	0.071
pH	0.170	0.112	0.019	0.350	0.201	0.070	0.870	0.196	0.171
CEC	0.410	0.219	0.090	0.860	0.149	0.128	1.000	0.243	0.243
IFI		0.377			0.322			0.637	

Table 7: Soil fertility comprehensive evaluation standard (Lv Xiaonan et al. 2000).

IFI	[0.8-1.0]	[0.6-0.8]	[0.4-0.6]	[0.2-0.4]	[0 -0.2]
Fertility Grade	I	II	III	IV	V
Fertility	Higher	High	Medium	Low	Lower

effect of subjective factor, the right choice should be made on the basis of the inherent relationship of soil fertility. In this paper, factor analysis method in the multiple statistical analyses is used to calculate the common factor variance, hereby the weight coefficient is determined. At first, five fertility indexes make a factor analysis to obtain the weight value and contribution rate of fertility factor principal component.

Common factor variance of soil fertility index (common degrees of common factor) is obtained by factor loading matrix, and its value represents contribution of soil fertility overall variance on the fertility index, thus obtaining the weight value of fertility index (Lv Xiaonan et al. 2000). The results are given in Table 5.

Calculation of soil fertility comprehensive index value: In accordance with addition-multiplication rule, additive synthesis is used in cross each other similar indicators to obtain comprehensive index value IFI of soil fertility (Integrated Fertility Index), the calculation formula (Lv Xiaonan et al. 2000) is:

$$IFI = \Sigma Wi \times Ni$$

Where, *Ni* and *Wi* represent respectively membership value and weight coefficient of *i* nutrient index. Membership value (*Mv*) of the index is calculated using membership function, as index value had been taken the conversion process, and the value of every index is in 0.1~1, the finally calculated comprehensive index value is in 0.1~1, then the calculated IFI of soil fertility can be divided into soil fertility grade according to certain standard. The results are given in Table 6.

CONCLUSIONS

According to the above calculation results and the evaluation standard, it is known that IFI of DaTong ecological wetland is 0.377, between 0.2-0.4, belonging to the class IV, the fertility is low; IFI of PanYi reclamation area is 0.322, between 0.2-0.4, belonging to the class IV, the fertility is low; IFI of XinZhuangZi reclamation area is 0.637, between 0.6-0.8, belonging to the class II, the fertility is high. In three reclamation areas, the order of soil fertility level is Xin Zhuang Zi reclamation area > DaTong ecological wetland > PanYi reclamation area. This may be due to the different covering soil thickness and different plantings on soil in three reclamation areas, thus the effect on fertility is also different.

Soil fertility is a number of factors, soil fertility factors are perplexing; to better reflect the integrated soil fertility level, the main factor affecting soil fertility or decision factors must be seized in order to achieve the purpose of accurate evaluation on soil fertility. Factor analysis method is used to determine the weight coefficient in this paper, which can eliminate interference of human factors, and compare with the actual, but index selection and classification need to be further improved.

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